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1. Your reference — P346711/NBR/MEA

2. Patent application number *(The Patent Office will fill in this part)* — 0403582.0 — 18 FEB 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Hamilton Erskine Limited, 17 Moss Road, Ballygowan, Newtownards, Co Down, BT23 6JQ, Northern Ireland

   Patents ADP number *(if you know it)* — 8676413001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — "Improvements Relating to Impact-Resistant Structures and Assemblies"

5. Name of your agent *(if you have one)* — Murgitroyd & Company

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — Scotland House, 165-169 Scotland Street, Glasgow, G5 8PL

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11. I/We request the grant of a patent on the basis of this application.

Signature Murgitroyd & Co. Date 17 February 2002
Murgitroyd & Company

12. Name and daytime telephone number of person to contact in the United Kingdom — Mark Earnshaw — 0141 307 8400

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Improvements Relating to Impact-Resistant Structures and Assemblies

The present invention relates to improved impact-resistant structures and assemblies such as walls and windows, including ballistic-, blast- and hurricane-resistant optically transparent composite materials involving glass.

In relation to windows, there have been many suggestions for "bullet-proof" and "blast-proof" transparent windows and the like, either for civilian purposes such as for use in aircraft, or for military purposes, especially protection against enemy and terrorist attack. However, with the developing threat from international terrorism and events such as those of September 11 2001, many governments and major organisations are re-appraising their security requirements. High velocity weapons and better explosives are increasingly available to terrorists and the like. Whilst traditional 'bullet-proof' glass will still

be required, there is now an increasing need for certain key installations, persons and equipment, especially in and around military and high governmental locations, to be protected against a higher level of threat than previously considered necessary.

Where pure optical transmission for a window is not a necessity, there are many available materials having high strength and impact resistance. However, where optical transparency of 'normal' windows and glazing is desired, e.g. for military base houses and offices, current forms of glazing are only adequate for protection against low velocity bullets (e.g. from small arms), and low levels of blast. Most current forms of 'bullet proof' glass use several layers of glass bonded by adhesive polymer film. The energy of the projectile is dissipated over increasingly large areas of blast. To some extent the projectile can be deformed or fragmented and can be deviated from the original line of attack. The energy is directed towards a direction different to the previous path, resulting in further dissipation of energy, e.g. as shown in figure 1.

Typical design solutions involve either glass/glass combinations or glass/polycarbonate (PC) combination. The latter offer an advantage in that they are lighter than the former, but they often have delamination problems. The effect of bonding of PC to glass is also difficult as PC has a

substantially higher rate of thermal expansion than glass. This causes high stress levels in the bonding interlayer during temperature changes which often leads to delamination.

The PC designs are often 'complex', particular as the level of protection required increases. The number of layers can cause problems with optical interference and secondary image formation because of the number of glass/PC interfaces. There may also be weight or thickness limitations preventing their use in particular applications. This is shown in the following table.

Weapon type & Calibre	Class	Design	Thickness (mm)	Weight (kg/m^2)	Transmittance (%)
Hand Gun 9mm Luger	BR2/C1	6^2PC$5^2$3-12-ESG6	35	47	77
Rifle 0.223 (5.56*45)hc	BR5/C3	$8^2 6^2$PC$6^2 6^2$PC6	39	71	64
		8^2PC$8^2$6-12-6^2PC$8^2$3-20-ESG6	82	95	?
Rifle 0.308 (7.62*51)	BR6/C4	$8^2 8^2 6^2$PC$6^2 6^2$PC6	49	93	?
		8^2PC$8^2$3-12-10^2PC$8^2$3-20-ESG6	85	102	?
Rifle 0.308 (7.62*51)hc	BR7/C5	$6^2 8^2 8^2$PC8-20-$6^2 8^2$82PC8	91	143	58

US5665450 discusses the introduction of glass fibres and glass ribbons into transparent composites, but, as it states, the introduction of glass fibres into an optically transparent polymer destroys the transparency of the polymer.

US5665450 considers that the introduction of glass ribbons provide a higher degree of optical clarity and lower level of distortion than glass fibres. However the photographs in US5665450 indicating the degree of optical clarity of fibre and ribbon-reinforced materials still show distortion even based on photographic reproduction of relatively indistinctive photographs.. Figure 7 shows percentage like transmission as a function of temperature and wavelength. However, it can be seen that the percentage transmission barely gets above 80% at the lowest temperature and highest wavelength measured. The lowest temperature measured is at 30°C, which is also not a temperature generally encountered in many countries on a regular basis. It is interesting that the percentage transmission in US5665450 was not measured at more temperate or freezing temperatures. Moreover, 80% optical transmission is very poor in comparison with the expectancy of 'normal' glass, which should be at least 90% at all temperatures. It is appreciated that the human eye can easily recognise or perceive a less than 100% optical transmission of light through a 'transparent' material.

In essence, there is a requirement for an optically transparent composite material having about or at least 90% optical transmission over a range of temperatures, including below 0°C, and also able to withstand high velocity ballistic projection whilst having a relatively low manufacturing cost.

According to one aspect of the present invention, there is provided an optically transparent composite material comprising at least one glass/resin/glass lamination, wherein the resin is a PRR material having optical fibre-reinforcement therein.

The term "PRR" refers to 'polycarbonate replacement resins', a range of materials provided by Chemetall GmbH of Frankfurt, Germany, and generally defined in their International Patent Application No WO 01/38087A1. The PRR materials are a range of transparent cast resins that can consist of reactive acrylate and methacrylate monomers, acrylate and methacrylate oligomers, bonding agents and initiators. The content of WO 01/38087A1 defining these materials is incorporated herein by way of reference.

The term "PRR" also extends to similarly provided polyurethane resins, often termed "PUR".

A range of commonly available PRR materials are sold under the trade name Naftlolan®. The Naftlolan materials are provided in a range of different formulations to provide slightly different

properties. A list of product data of certain polyurethene Naftlolan materials are listed in Tables 2 and 3 hereinafter, by way of example only. PRR materials have been found to have several advantages over previously used polymer glass lamination layers. Firstly, the refractive index of PRR material overlaps very closely with many types of glass. Secondly, PRR materials have been found to expand and contract at very close rates with that of glass, thus leading to minimal if ever cracking or delamination (due to internal stress) during any thermal expansion and contraction of the composite material. Thirdly, PRR materials are relatively very easy to use and set in transparent composite materials, especially compared with processes of curing previously used types of polymers and resins. They are also useable in designs incorporating complex curves.

Because PRR materials have a co-efficient of expansion and contraction very close to glass, these materials are usable to provide optically transparent composite materials with glass over a much greater range of temperatures than, e.g. that shown in US5665450. In particular, the present invention is designed to provide a ballistic-resistant optically transparent composite material which is usable at temperatures even as low as -15°C to -40 °C, generally -20°C, e.g. the temperature of windows in military installations in certain countries such as Canada, as well as temperatures going up to 30°C to 40°C, such as the temperature of

windows in more tropical countries. To that extent, the difference in co-efficiency of glass, such as a normal silica-based glass, and PRR materials, deviates little over a wide temperature range.

Table 4 hereinafter lists the refractive indices of a number of resins, including a number of the Naftolan range, indicating their close refractive index to that of glass in general.

In general, the refractive index of the PRR materials are sufficiently close to readily available types of glass, such as a silica-based glass, that the optical transparency of the composite material of the present invention is as good as that from any current glass/glass or glass/PC laminations.

The fibre reinforcement in the PRR layer of the composite material of the present invention can be provided by any know type of "fibre material", being for instance in the form of filaments, or in the form of particles such as beads, or even powders, as long as such fibre material wholly or very substantially has the same refractive index as glass across all or most the wavelengths of optical light. Such glass fibres are well known in the art, one such available product being sold under the trade name Tyglas by Fothergill Engineered Fabrics.

The fibre reinforcement provide the PRR intermediate layer with improved strength because of their well

known ability to laterally transmit impact energy. Meanwhile, PRR materials also have improved utility as a resin to band the fibre material fillers because of their similar co-efficient of thermal expansion and adhesive strength to glass.

In the present invention, the thickness of the glass and PRR layers, and the density of fibre reinforcement in the PRR layer, can vary according to the qualities of the final composite material desired. Cost and physical properties are factors in considering the thickness of the layers.. One known ratio of thickness is glass/PRR/glass of 6/20/4mm; this is provided by way of example only. Another suitable dimension is 4/4/3mm.

Indeed, a major facet of PRR material is that its strength is independent of its thickness. Many types of resins and adhesives only have strength for a minimal thickness, as their use is to bond together the layers (e.g. of glass) on each side, rather than provide any inherent strength of their own right. PRR has been found not only to provide good bonding to glass, but also have internal strength in its own right. The thickness of the PRR layer is therefore independent of the thickness of the glass layers either side.

The nature of "high velocity ballistic protection" can be defined in general terms as the difference between a hand gun and a rifle, e.g. above a NATO 5.56 or 7.62mm ball.

According to a second aspect of the present invention, there is provided a process for making an optically transparent composite material as herein before defined, comprising the steps admixing the PRR material with the optical fibre-reinforcement, and allowing the combination to cure and set between the two layers of glass.

Further information on the curing of PRR resins may be found in WO 01/38087A1.

Meanwhile, increasing power and sophistication of explosive-technology means that 'blast-proof' optically transparent material is also desired having increasing in situ strength and load ability. In this regard, it is now generally desired to provide blast-resistant optically transparent material having the ability to withstand a blast of 500kg TNT or equivalent at 40m.

US patent No 3953630 discloses a laminated transparent assembly suitable for use as a windscreen for a high speed vehicle wherein high strength flexible material is embedded in a plastic material, laid between two layers of glass. The flexible material extends beyond the transparent assembly, so as to be directly conjoined with the structure of the vehicle. Thus, as any blast causes deformation of the transparent assembly (as part of the impact absorption), the high strength flexible material provides a direct bond between the vehicle structure bolts and the transparent assembly,

hopefully thereby resisting complete separation of the two and travel of the transparent assembly into the vehicle.

However, US3953630 has three major disadvantages. Firstly, it only discloses the use of polyvinylbutyral (PVB) as the plastic layered to provide the bonding between the glass sheets and the flexible material. Manufacture of the transparent assembly in US3953630 requires an altering of the conventional laminating technique, in order to provide good bonding between a number of PVB sheets, and the glass. This requires pre-heating treatment, insertion of the full assembly including glass sheets in a closed bag to evacuate all air, followed by heating in a autoclave with high pressure. This method of manufacture has not lent itself to cost-efficient production for a number of transparent assemblies, other than for the very special uses such as our aircraft windscreens as mentioned.

Moreover, PVB in particular is a material only designed to provide good bonding between glass layers. It is typically only 1-2mm thick. Further thickness of layer is not desired, as PVB has little internal strength in its own right.

Thus, in a third aspect of the present invention, there is provided a laminated optically transparent assembly comprising at least one glass/resin/glass lamination, and having one or more high tensile strength flexible material reinforcement pieces

extending laterally from the resin layer to provide attachment of the assembly to a surround, wherein the resin is a PRR material.

PRR materials are those as defined herein above. As well as the greater similarity of refractive index and co-efficient of thermal expansion of PRR material to glass, the PRR-flexible material and PRR-glass bonding has been found to be superior to that of prior materials such as PVB.

Meanwhile, the assembly of the present invention still provides the degree of flexibility desired for a blast-resistant window, with the reinforced attachment of the window to the surround, such as the window rebate of a frame.

The high tensile strength flexible material may be similar to that disclosed in US3953630, i.e. woven fabric or woven glass fibre material or polyester fibre material. One such product is Kevlar®.

The flexible material could extend wholly or substantially around opposites sides of the complete transparent assembly, to provide flexibility of attachment to the surround. It could also extend as a series of discrete straps.

For the ballistic-resistant material described hereinabove, the thickness of the glass and resin layers of the blast-resistant assembly can follow those well known in the art. One suitable dimension

for the glass/resin/glass in 4m glass, 4mm PRR and 3mm glass.

The thickness of the PRR layer can indeed be up to 40-50mm thick, as PRR has inherent strength independent of thickness as mentioned above. To that extent, the PRR material can be as thick and therefore as strong as desired, as all the strength from a blast is taken by the resin (whilst any glass shatters).

The second disadvantage of US3953630 concerns its design. All the windows in the examples shown in US3953630 are rigidly attached to or through the window frame. If the frame fails, the window will then be unattached, and so 'fail'.

According to a fourth aspect of the present invention, there is provided a laminated transparent assembly comprising at least one glass and one resin lamination, and having one or more high tensile strength flexible material reinforcement pieces extending laterally from the resin layer to provide attachment of the assembly to a subframe and/or wall.

By direct attachment of the transparent assembly, generally a window, to the subframe and/or wall, any weakness in the impact-resistance of the assembly because of weakness and/or damage to the frame, generally a window frame, is avoided. This allows a

larger load on the transparent assembly to be supported by the subframe and/or wall.

A third disadvantage of US3953630 is the lack of reinforcement in the window pane.

Thus, according to a fifth aspect of the present invention, there is provided a laminated transparent assembly comprising at least one glass and at least one resin lamination, and having one or more high tensile strength flexible material reinforcement pieces extending laterally from the resin layer to provide attachment of the assembly to a surround, wherein the resin layer includes directional fibre reinforcement at or near each edge of the resin layer, and wherein the or each reinforcement piece loops around the fibre reinforcement.

The fibre reinforcement may be any suitable reinforcement means known in the art. As it is intended only to be at or near the edges of the assembly, the reinforcement pieces need not be in any way wholly or partly transparent, and could even be hidden within any framing used for the assembly, such as a window frame.

Preferably the fibre reinforcements are unidirectional glass fibres, whose direction follows the edge direction of the resin layer. More preferably, the fibre reinforcements are cast in the resin layer simultaneously with casting of the resin.

The fourth and fifth aspects of the present invention described above are not limited to the use of a PRR material as the resin, and are equally applicable to the use of other resin materials such as polycarbonate (PC) and/or PET.

The flexible material reinforcement pieces suitable for the above aspects of the present invention may be pieces of wepping or similar as are well known in the art, and as hereinbefore described. Preferably, the pieces are of sufficient length to allow their attachment along from the glass and resin part, and/or any assembly frame involved, such as a window frame.

According to another embodiment, some slack is allowed in the extent or length of the flexible material reinforcement pieces extending from the resin to allow some flexibility in the absorption of a shock load. This is contrary to the rigid system of attachment in US3953630.

These aspects of the present invention provide two advantages.

Firstly, impact loading on the laminated transparent assembly, generally a window, is passed through or across the frame to the subframe and/or wall, such that the frame can fail but the window remains attached or 'in place'. Secondly, the reinforcement pieces (preferably with some slack therein) have sufficient 'give' in them to reduce the shock

loading, meaning less loading is put on the subframe and/or wall.

An example of such a laminated transparent assembly, as shown in Figure 4 herewith, has been tested by the UK Home Office against a 100kg charge at a stand-off of 21m, and has withstood the blast successfully.

In the present invention, the ability to provide a PRR layer of any thickness provides a further benefit.

Thus, according to a sixth aspect of the present invention, there is provided a blast-resistant composite material comprising at least one layer of PRR material having at least one reinforcement piece extending wholly or substantially across the PRR layer.

Preferably, the reinforcement piece is a strip or bars or other reinforcement means. There is preferably a series of such pieces, more preferably forming a grid or grid-like structure wholly or substantially across the composite material. An example is shown in Figure 5 herewith.

The PRR material is that as defined hereinabove. The reinforcement piece can be one or more of woven roving, webbing, webbing material or even metal material. The use of a metallic grid provides the same effect as a "muntin" system which uses metallic

reinforcement grid alongside a glazing panel, but not actually therein. The present invention therefore achieves the same effect and strength as a muntin system, but as a one piece assembly, thereby significantly reducing assembly and installation.

The blast-resistance is achieved because the PRR layer can be any thickness desired, e.g. up to 40-50mm, which is able to accommodate reinforcement pieces, whereas previous resins were not able to achieve such thickness, and thereby accommodate reinforcement therein.

The benefit of achieving reinforcement within the PRR material is that each 'section' created by the reinforcement piece or pieces, e.g. each small section within the grid, can be regarded as having its own frame, as thus regarded as a separate section in terms of analysis against blast. As is well known in the art, the blast-resistance of a small section is greater than that of a large section. By dividing the composite panel into a number of small sections, significant blast-resistance is achieved.

It is noted that the optical transparency of blast-resistant panels using for example the muntin system is not as important as that described for other aspects of the present invention, so that the comparative refractive index is not as important as that as described above in relation to other aspects of the present invention.

Turning to impact-resistance structures, a further important feature of any impact-resistant window is ensuring that the surrounding frame and even the surrounding wall are sufficiently strong to support the window and survive the impact such as a explosive blast. Any system with little or no 'give' i.e. a rigid system, suffers much higher stresses the one which allows some flexibility, elasticity or give within it. Even apparently rigid structures such as walls will flex under loading.

The present invention therefore also provides a surface-reinforcement assembly designed to allow flexibility to a surface such as a wall, floor or ceiling or the like, whilst also reinforcing its strength.

Thus, according to a seventh aspect of the present invention, there is provided a wall-reinforcement assembly for a wall having an adjacent floor and ceiling, comprising a first wall-adjacent layer formed wholly or substantially of fibre reinforced composite flexible material, and a second layer comprising one or more high tensile strength flexible material reinforcement pieces, wherein at least one of said reinforcement pieces is secured to the floor and the ceiling.

The terms "wall", "floor" and "ceiling" are interchangeable in the sense that the wall-reinforcement assembly is usable on a floor, wall or ceiling, having appropriate other structures

therearound to form an internal part of a building or the like. The reinforcement pieces are preferably, secured to a 'strong' floor, such as made of concrete, and a 'strong' part of a ceiling such as a reinforced concrete ring beam or steel I-section now commonly used in building construction, more preferably through set fixing points.

The first composite layer is preferably a sheet of glass fibre reinforced plastic or kevlar material, either loose or in resin, which is able to extend across the area of the wall to be reinforced. In particular, this layer provides a layer of protection from small fragments being dislodged by any blast or other impact causing flexing of the wall. The thickness of this layer can be varied to bolster the physical attack and ballistic protection of the wall.

The second layer preferably comprises a series of parallel straps, such as webbing straps. The reinforcement pieces could run horizontally, as well as vertically, or indeed both. The material of the reinforcement pieces is selected for its strength and ability to stretch under shock loading.

The assembly could include a third layer adapted to provide a suitable internal finished layer, as well as possibly including the appropriate level of installation, fire resistance, etc. and internal fittings such as electrical sockets.

The assembly could be retrofitted to an existing wall or other surface, or included as part of a purposed built design.

The assembly could be formed to be the size of the wall or other surface on which it is to be located, or be formed in modular form, e.g. made in panels, which are joined together to make the desired or necessary size in-situ.

In general, the present invention provides the ability to consider the impact-resistance across a complete portion of a building, especially a wall which can include one or more windows, doors or other openings.

Thus, according to an eighth aspect of the present invention, there is provided an impact-resistant system comprising the conjunction or combination of two or more aspects of the present invention hereinbefore defined.

An example of the system includes a wall-reinforcement assembly as hereinbefore described, in combination with a laminated transparent assembly as hereinbefore described in a form of a window, wherein the flexible material reinforcement pieces of the assembly combine with the flexible material reinforcement pieces of the window assembly. In this case, the window reinforcements are attached to the frame.

In a second example, the material reinforcement pieces of a wall reinforcement assembly as hereinbefore described extend internally through a window assembly as hereinbefore described, such that the reinforcement pieces are secured by the cast resin in the window, and are of sufficient length to enable the pieces to be secured at the fixing points at the top and bottom of the wall being reinforced by the assembly. This design also allows for securing non-glass windows such as polycarbonate, which may be desired where the emergency or hazardous nature of the work conditions are not suitable for handling glass.

It will be recognised by these skilled in the art the composite materials and assemblies could also be used to provide hurricane or the like resistance, and thus the present invention is extended thereto. The term "impact" as used herein refers to any type of severe blow such as an explosion, bullet, wind, etc. Blast-resistance generally relates to resistance against an explosion.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is schematic cross-sectional view of the impact of a projectile against a current multi-glass laminated windowpane;

Figure 2 is a cross-sectional view of a optically transparent composite material according to one embodiment of the present invention;

Figure 3 is a laminated optically transparent assembly according to a second embodiment of the present invention;

Figure 4 is a perspective photograph of a laminated optically transparent assembly according to a third embodiment of the present invention;

Figure 5 is a schematic front view of a reinforced laminated optically transparent assembly according to a forth embodiment of the present invention;

Figure 6 is a cross-sectional part view of a laminated optically transparent assembly according to a fifth embodiment of the present invention attached to a wall and subframe;

Figure 7 is a perspective photographic view of a wall-reinforcement assembly according to a sixth embodiment of the present invention; and

Figure 8 is a schematic front view of a laminated optically transparent assembly according to an eighth embodiment of the present invention.

As previously mentioned, Figure 1 shows how the energy of a projectile is dissipated over increasingly large areas of glass of a known glass

PC lamination pane, leading to a large area of glass shattered from the left hand side.

Figure 2 shows a optically transparent composite material 2 comprising a glass/resin/glass lamination. Within the PRR resin layer 4 are a series of traditional fibre glass woven rovings 6.

To produce the material, the rovings 6 were secured between two panes of glass 8, and the PRR resin 4 was injected into the cavity. The resin 4 flows up the inside of the glass 8 and disperses through the woven roving 6, wetting the fibres and forming an excellent bond.

Figure 3 shows a blast-resistant assembly 10 mounted to a wall 12. Between the two panes of glass 14, a 2 inch wide unidirectional glass fibre woven roving 16 was bonded into the same PRR resin 18 as mentioned above. The complete assembly 10 was located in the rebate of a window frame 20, and the roving reinforcement material 16 fixed to the frame 20 by adhesive, and also by means of a lateral bolt 22.

The assembly 10 was tested in a Hannsfield 20k-w tensometer. Loads in access of 8000N were applied before the fibre woven 16 broke. Considerably greater loads could be achieved with the use of thicker fibres or different types of fibres.

Figure 4 shows a similar blast-resistant window assembly 30 as that partly shown in Figure 3, but wherein the PRR resin intermediate layer includes a complete loop of unidirectional glass fibre 32 around the perimeter of the resin and glass lamination and inside two panes of glass. Lengths of webbing material 34 acting as high tensile strength flexible material reinforcement pieces are wrapped around the loop of unidirectional glass fibre 32, and the loose ends of the webbing material 34 extend outside the glass and resin lamination. Thus, the lengths of webbing material 34 are bonded into the resin layer, and are also wrapped around the unidirectional glass fibre 32 that is bonded into the resin. The loose ends of the webbing material 34 are then secured by a bolt 38 directly to a subframe or wall 36 as shown in figure 6.

The arrangement in Figure 6 means that the glass/resin lamination is directly secured in place by the webbing material 34 rather than by any securement into a window frame or rebate. This allows for the use of different types of webbing or other materials as the reinforcement pieces to ensure the correct strength as required and to absorb an appropriate shock load.

The length or webbing material 34 can also be adjusted to allow some slack, which further assists with the absorption of a shock load. In this way, failure of the window frame or rebate does not result in detachment of the window from the wall.

Moreover, the loading against the window is passed through to the subframe or wall 36.

Figure 5 is schematic front view of a blast-resistant composite material for a window or similar wherein a series of horizontal and vertical reinforcement webbing straps 38 extend through the intermediate resin layer to form a net or a grid pattern. The webbing pieces 38 could extend further so as to be part of the webbing arrangement shown in Figure 7.

Figure 7 shows a wall-reinforcement assembly comprising a first wall-adjacent layer 40 formed from glass fibre reinforced plastic material. This layer of 40 provides protection from small fragments being dislodged from the wall following any blast impact. The thickness of the layer could be varied improve to the physical attack and ballistic protection of the wall. A second layer 42 comprises a series of vertical webbing straps running between fixing points in the floor 44 and ceiling 46. Once again the webbing straps act as high tensile strength flexible material reinforcement pieces, and their actual material and width can be chosen to achieve the correct balance of strength and elasticity/stretch for a shock loading.

The arrangement shown in Figure 7 was able to resist a charge of 500kg of TNT equivalent at a distance of 17.5m from a wall of brick and block with a cavity foam insulation, similar to 'standard' house-wall

construction in the UK. That is, the blast did not puncture the reinforcement assembly.

Figure 8 shows a window assembly similar to that shown in Figures 3 and 4, wherein the reinforcement piece 50 extending laterally from the resin layer has a series of holes, through which suitable reinforcement pieces such as webbing straps 52 can be entered, so as for attachment to a wall or subframe, or also to be the reinforcement pieces for use in Figure 7. That is, the wall-reinforcement assembly in Figure 7 is able to accommodate opening such as windows and doors, and the reinforcement pieces can be conjoined or interlinked or formed as one, so as to provide the strongest arrangement for strength and elasticity across the whole wall surface.

The present invention provides ballistic-resistant and blast-resistant assemblies providing protection against much higher levels of protection from high velocity weapons and explosives than currently known with current forms of wall and glazing. Production of the assemblies is also comparatively simple and cost effective compared to previous types of similar assemblies, which used less suitable polymers and plastic material.

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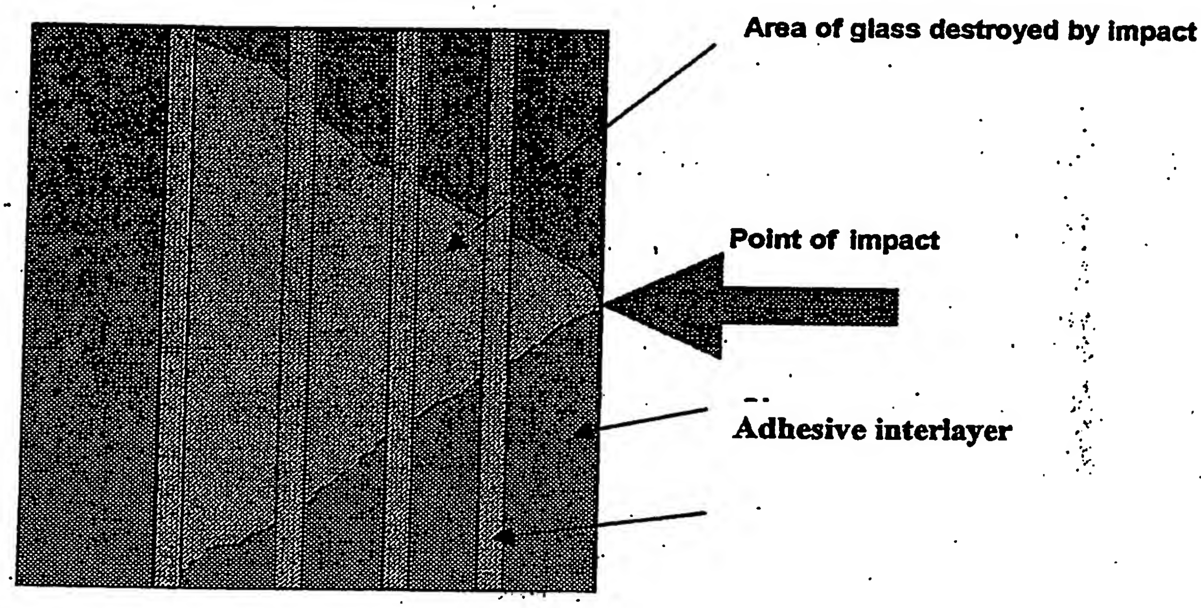


Area of glass destroyed by impact
Point of impact
Adhesive interlayer

Fig 1

Fig 2

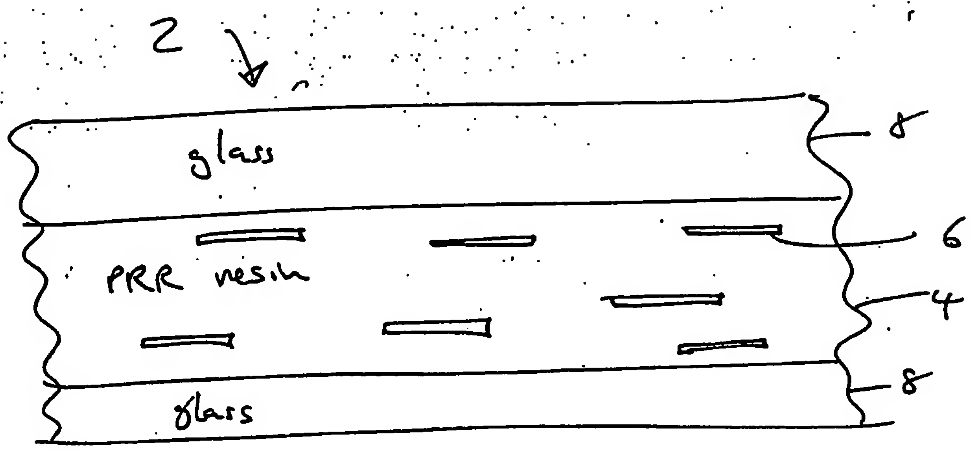


Fig 5

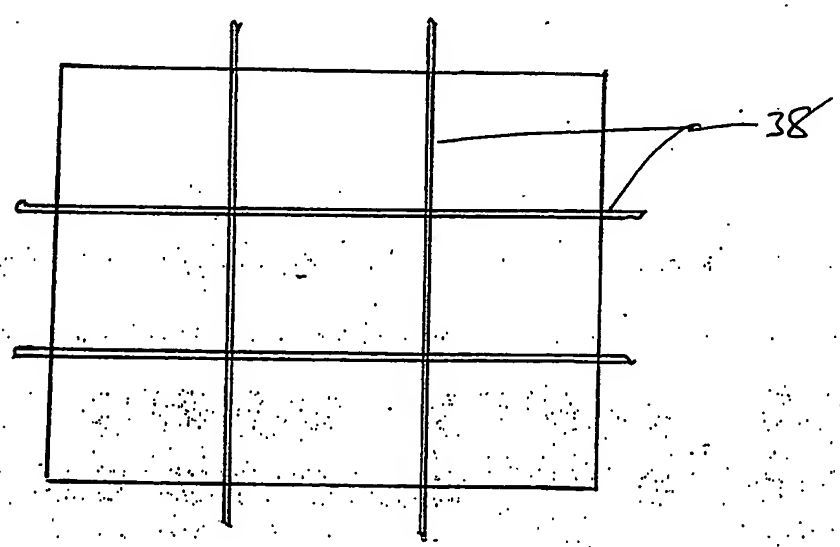
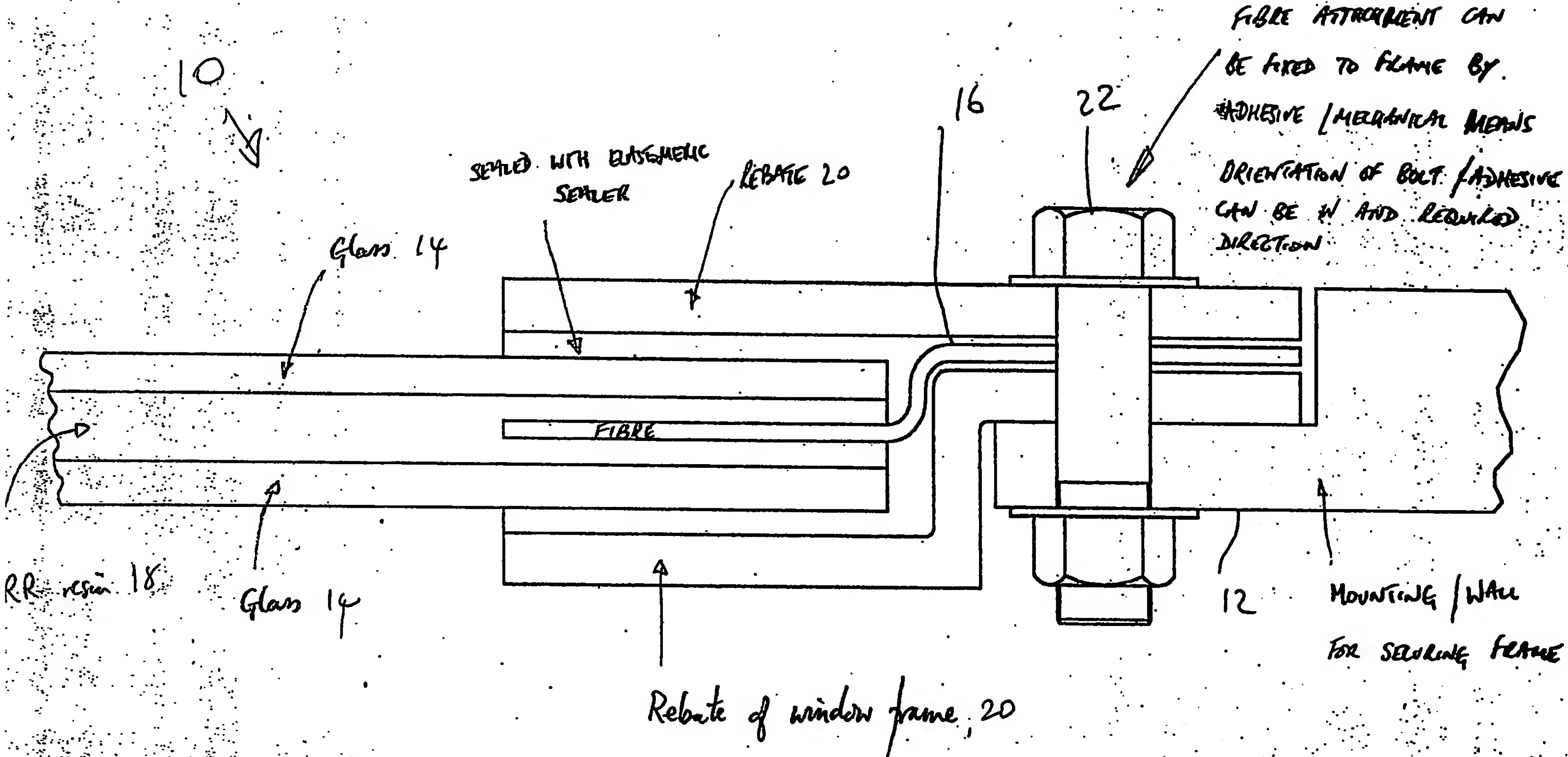


Fig 3


10
Glass 14
SEALED WITH ELASTOMERIC SEALER
REBATE 20
16
22
FIBRE ATTACHMENT CAN BE FIXED TO FRAME BY ADHESIVE / MECHANICAL MEANS
ORIENTATION OF BOLT / ADHESIVE CAN BE IN ANY REQUIRED DIRECTION
FIBRE
RR resin 18
Glass 14
Rebate of window frame, 20
12
MOUNTING / WALL FOR SECURING FRAME

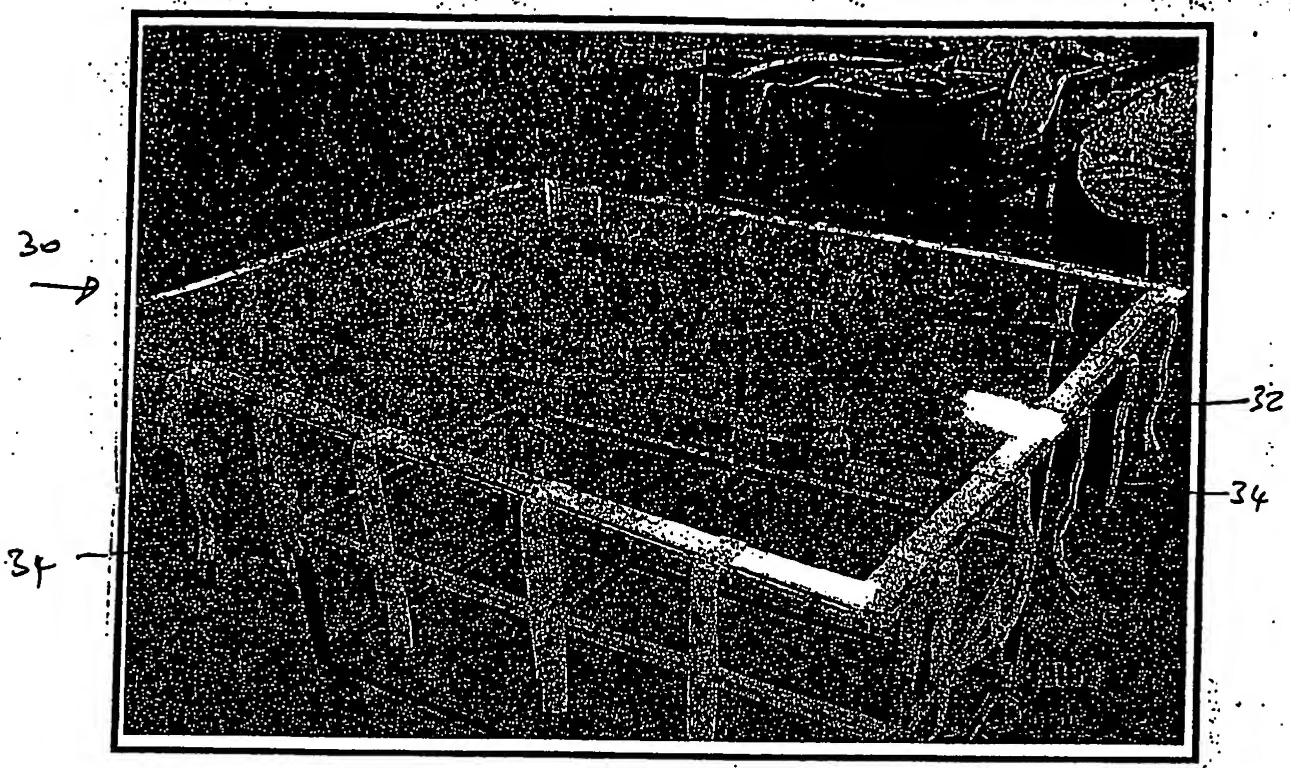

30
32
34
34

Fig 4

Fig 6

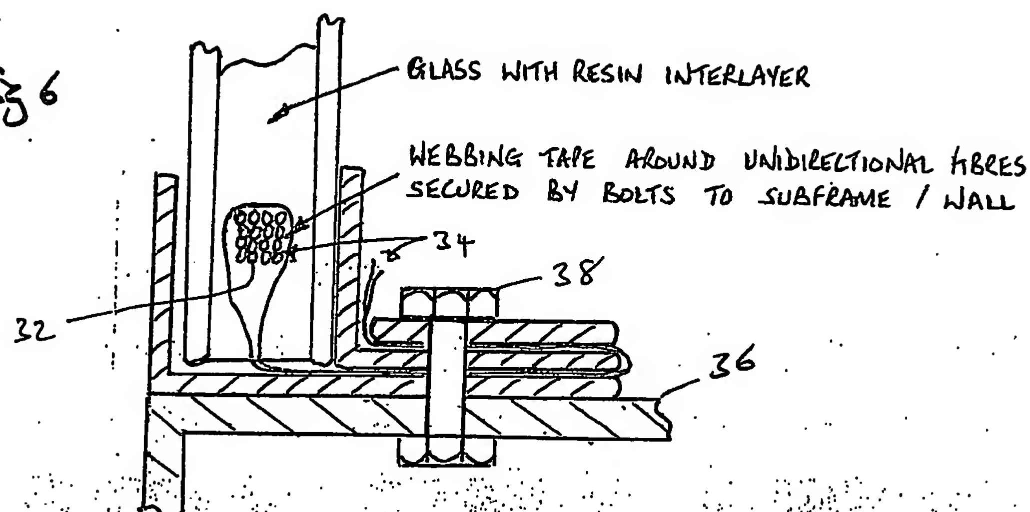
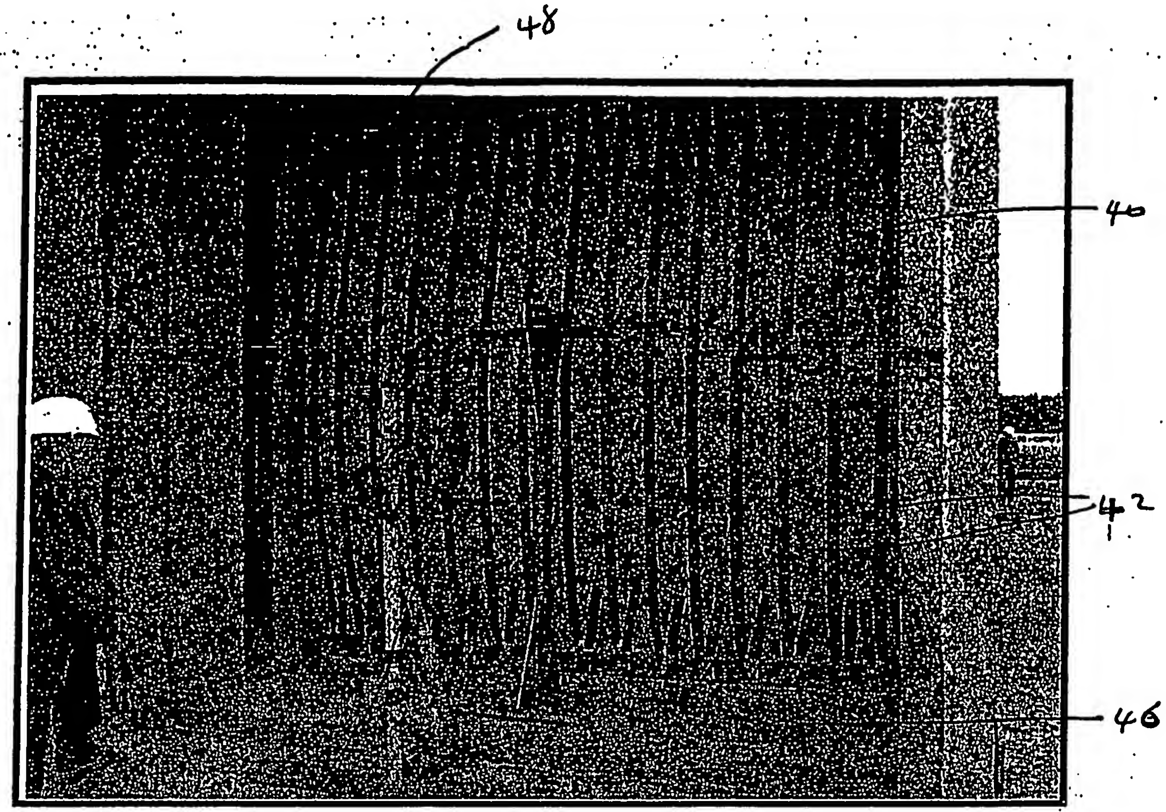
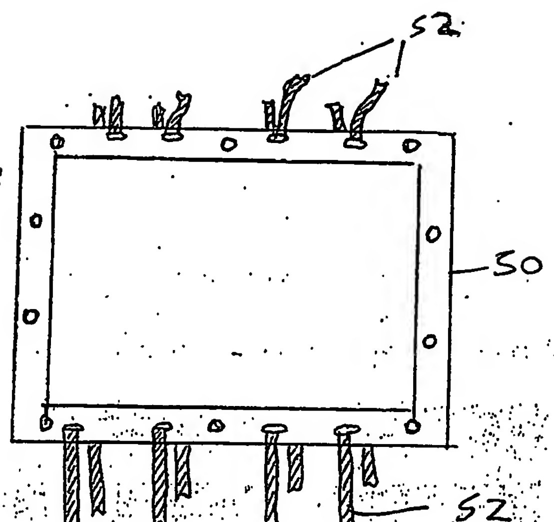

GLASS WITH RESIN INTERLAYER
WEBBING TAPE AROUND UNIDIRECTIONAL FIBRES SECURED BY BOLTS TO SUBFRAME / WALL
34
38
32
36

Fig 7



Charge 500kg at 17.5 m,

Fig 8



Product Data of Polyurethan Composite Materials

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Physical Properties	Naftolan PU-A 700 / PU-B 304	Naftolan PU-A 208 / PU-B 606	Naftolan VP-PA 0911 / VP-PB 2110	Naftolan VP-PA 1011 / VP-PB 2110	Naftolan VP-PA 2601 / VP-PB 2110	Naftolan VP-PA 0511 / VP-PB 2910	Standard
Density							
lax							
lin							
ange possible in one layer							
Strength & Stiffness							
ensile strength [Mpa]	16	16	19	18	5	2.1	DIN 53 504
5% module [Mpa]	5	1.2	15	6	1.2	0.7	DIN 53 504
0% module [Mpa]	6	1.7	14	7	1.8	1.2	DIN 53 504
00% module [Mpa]	8	2.5	15.5	10	3.2	1.9	DIN 53 504
ensile modulus							
ensile yield point							
longation at break [%]	180	360	150	160	150	120	DIN 53 504
ompressive strength							
ompressive modulus							
ompressive yield point							
lexural strength							
lexural modulus (also called modulus of elasticity)							DIN EN ISO 527
lexural yield point							
-plane shear strength							
-plane shear modulus							
oughness							
ariation with loading rate							
ardness							
hore A hardness	90	73	95	90	65	55	DIN 53 505
dhesion to glass							
ond shear strength							
ompression shear strength [Mpa] 4/2/4 mm glass/ glass	18	7.5	20	20	10	2.5	
hermal							
hermal coefficient of expansion							
hermal conductivity							
pecific heat capacity (at 20 oC)							
esistance							
esistivity							
emperature coefficient of resistance							

nese values are for guidance only and do not represent a specification.

Product Data of Polyurethan Composite Materials

?hysical Properties		Naftolan PU-A 700 / PU-B 304	Naftolan PU-A 206 / PU-B 606	Naftolan VP-PA 0911 / VP-PB 2110	Naftolan VP-PA 1011 / VP-PB 2110	Naftolan VP-PA 2601 / VP-PB 2110	Naftolan VP-PA 0511 / VP-PB 2910	Standard
?lammability								
?elting point		Because of the moleculare structure, the materials do not melt and boil						
?oiling point		Because of the moleculare structure, the materials do not melt and boil						
?moke emission								
?ritical Oxygen Index (COI) (minimum oxygen fraction in ?n oxygen-nitrogen mixture which will support steady ?tate combustion of the plastic. Plastics with COI >0.21 ?re self extinguishing)								
?hemical Resistance								
?cids								
?lkalis		The materials are not resistant against Alkalis						
?rganic solvents		The resistance against organic solvents depends very much on the tested solvents						
?eatherability/degradation								
?geing – temp cycling test		Tests according to DIN 1286 with different kind of laminates were passed without failures.						
?V absorption		See the transmission datas on the next sheets						
?dsorption of water								
?dditional Data								
?iscosity (23°C) [mPa's]	Component A	450	320	600	515	435	360	
?scosity (23°C) [mPa's]	Component B	3250	85	85	85	85	85	
?scosity (23°C) [mPa's]	Mixture	2550	200	225	200	245	230	
?pecific weight (23°C) [g/cm³]	Component A liqu	1.02	1.01	1.03	1.02	1.02	1.01	
?pecific weight (23°C) [g/cm³]	Component B liqu	1.04	1.05	1.05	1.05	1.05	1.05	
?pecific weight (23°C) [g/cm³]	Mixture liquid	1.04	1.037	1.04	1.03	1.03	1.02	
?olume Shrinking [%]		2	2	4	4	3	2	
?ocessing time (23°C) [min]		45	15	40	30	30	30	
?uring time(23°C) [h]		12	48	12	24	24	12	
?orage time before delivery (18°C to 23 °C) [d]		4	6			4		
?hore A hardness after 1 day (cured resin) DIN		65		75	65	50	40	
?hore A hardness after 7 days (cured resin)		90	73	95	90	65	55	
?ermal coductivity (DIN 52612) [W/(m*K)]		0.18						DIN 52612
?ansmittance (DIN 67507) (assembly 6/8/4mm) [%]		90						DIN 67 507
?ansmittance (DIN 67507) (assembly 6/15/4mm) [%]		88						DIN 67 507
?ansmittance (DIN 67507) (assembly 6/20/4mm) [%]		88						DIN 67 507

?ese values are for guidance only and do not represent a specification.

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Table 4

Refractive Index
liquid / cured Resins (at 20°C)

Resin	n_{D20} liquid	n_{D20} cured
UV 11	1,4362	-
UV 22	1,4417	-
UV 33	1,4396	1,4813
ICE-Gießharz EP 1309-103	1,4434	-
UV 203	1,4370	-
S 700 M	1,4299	1,4713
S 696 M	1,4272	-
Naftolan VP-PA 0511	1,4542	-
Naftolan VP-PA 1011	1,4568	-
Naftolan PU-A 206	1,4540	1,4844*
Naftolan VP-PB 2110	1,4169	-
Naftolan PU-B 606	1,4777	-
Naftolan VP-PA 2601	1,4553	-
Naftolan PU-A 700	-	-
Naftolan PU-B 304	1,4739	-

* cured with corresponding B component